ENVIRONMENTALLY BALANCED SUGARCANE INDUSTRY IN EGYPT

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ABSTRACT

Sugarcane industry in Egypt goes back to the year 710 AD. Cane plantations are concentrated in the area of Upper Egypt. The total amount of cane cultivated in Upper Egypt is about 16 million tons per year. There are eight sugarcane producing factories in Egypt, most of them located close to the cultivations.

Sugarcane production generates considerable amount of waste during the harvesting phase of cane plantation and during the industrial phase of sugarcane milling. The sugarcane industry in Egypt can be currently defined as an open industrial system that consumes material and energy and creates products and wastes. For sugarcane industry to become a sustainable industry or a green industry, its production process has to be closed over its lifecycle in order to reach zero waste. Its wastes, residues and by-products should not be burned or disposed but should be rather treated as raw material for other industries. The sugarcane industry in Egypt needs to introduce the concept of industrial ecology or environmentally balanced industrial complex (EBIC) to close the material's loop.

This paper gives a background of sugarcane industry in Egypt for the different stages of production of sugar. It also reviews the different options for reuse of the produced by-products and residues as practiced in Egypt and worldwide. It then proposes an approach for introducing the concept of environmentally balanced industrial complex to sugar cane industry in Egypt to approach zero pollution.

Key words: environmental balanced industrial complex, sugarcane industrial waste, industrial ecology, green industry

INTRODUCTION

Sugarcane industry in Egypt is one of the oldest in Egypt. Cane plantations are concentrated in the area of Upper Egypt specifically in Menia, Sohag, Qena, Luxor and Aswan. The sugarcane cropping pattern, cultivated areas and its uses are shown in Table 1. According to these figures, the total amount of cane cultivated in Upper Egypt is about 16 million tons per year.

Table 1. Sugar Cane Cropping Pattern, Cultivated area and its uses [1]

Governorate	Area (hectare)	Yield (ton/hectare)	Area of Sugar Cane in each use (hectare)			
			Sugar Factories	Black Honey Factories	Seed	Juice
El Menia	15337	122.909	4163	3316	402	7455
Sohag	6723	125.694	3570	0	71	3081
Qena	62895	126.802	59417	2209	1102	166
Luxor	9688	127.348	9511	0	166	10
Aswan	32895	129.079	32032	0	765	98
Total	127537	126.904	108695	5525	2507	10811

As sugar industry is based on the availability of the canes, sugar factories are situated within the cane growing areas normally within 25 km distance from the farms [2]. There are eight cane sugar producing

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factories in Egypt, most of them located in Upper Egypt close to the cultivations. All eight mills are owned and managed by the Egyptian Sugar and Integrated Industries Company (ESIIC).

Table 2. Areas, capacities, inputs and outputs of the sugarcane mills [1]

Governorate	Factory	Area (Hectare)	Factory Design Capacity (tons)	Cane Processed in the Mill (tons)	Sugar Produced in the Mill (tons)	Percentage Contribution to Sugar Production
El Menia	Abou Korkas	4163	700,000	408,085	45,868	4.5
Sohag	Gerga	5188	900,000	531,633	60,107	5.9
Qena	Nagaa Hamadi	1428	1,700,000	1,435,137	166,296	16.4
	Deshna	8132	1,000,000	811,497	90,741	9.0
	Kous	16003	1,600,000	1,496,836	165,175	16.3
Luxor	Armant	13288	1,300,000	1,320,602	148,568	14.7
Aswan	Edfu	14054	1,100,000	1,199,351	136,775	13.5
	Komombo	19048	1,800,000	1,821,253	199,955	19.7
Total		81305	10,100,000	9,024,394	1,013,485	100

In Egypt, cane is manually cut in the field and the cane tops and dry leaves are manually peeled as they contain little sucrose and high starch, thus reducing the sugar yield required by the mills. The leaves also have high silica content which causes mill role wear. The cane is loaded on animals or small tractors to be then loaded on factory railcars or private trucks to be transported to the sugar mills.

The cane train consists of 25 carts. Each cart is loaded with 10-15 tons of cane. The carts are given numbers according to the cane owner. The carts are weighed in the factory and the weight of the cart is subtracted. The amount of waste leaves are calculated and also subtracted. The cane arriving in the mills is weighed and is immediately processed as sugarcane undergoes deterioration of the sucrose content if it is stored for later processing [3].

The residues of sugarcane consist of "green tops" (20% of the total harvest) and dry leaves (5% of the total harvest). It is estimated that these residues amount to 2.5-3 million tons per the five months of harvest.

At the mill, the cane is mechanically unloaded, and weighed. After weighing, the cane is conveyed to the crushers where its hard structure is broken using revolving knives, shredders and crushers. The crushed cane is conveyed from one mill to another and water is added to enhance the extraction of juice in a process called "inhibition" [3]. At the last mill, crushed cane or bagasse exits. The extracted juice from the mills is strained to remove large particles and then clarified to remove non-sugar impurities.

Clarification is done using lime and small quantities of soluble phosphate. The lime neutralizes the organic acids and temperature of the juice is raised to about 95°C. A heavy precipitate or 'mud' is formed and is separated from the juice by gravity or centrifuge. The mud is filtered and the 'filtercake' is washed with water [3].

The clarified juice goes to a series of evaporators to concentrate the juice. Steam from boilers is used to heat the first evaporator and steam generated from the first evaporator heats the second and so on. The temperature decreases from evaporator to evaporator and so does the pressure which allows the juice to boil at lower temperatures in the following evaporator. The syrup produced from the evaporator station is 65% solid and 35% water. The syrup is then clarified using lime, phosphoric acid and polymer flocculent, aerated and filtered.

From the clarifier, the syrup goes to the vacuum pans for crystallization. The syrup is evaporated in the pan boiling process until it reaches supersaturation where the crystallization process is initiated by "seeding" the solution. "Massecuite", which is a mixture of liquor and crystals, is formed in the evaporation pan and is discharged to the crystallizer to maximize the sugar removal from the massecuite. Then the massecuite is transferred to high speed centrifugals where "molasses" or mother liquor is centrifuged to the outer shell and the crystals remain in the inner centrifugal basket. The crystals are washed with water and the wash water is centrifuged from the crystals [3]. The crystallization process produces three grades of molasses; A, B and C from the different stages of centrifugation. The crystals are cooled, packed and stored.

Molasses produed from the sugar mills is a very valuable co-product. It amounts to 4% of the weight of the cane entering the mill. Its moisture content is 78-80% with sugar content of 50-55% of the solid matter. Molasses produced from the sugar mills of Upper Egypt are utilized in fermentation processes, aerobic processes to produce bread and fodder yeast and carbon dioxide used in food industry, as well as in the production of alcohol used in other industries such as vinegar production, perfumes and medical solutions.

Sugar production is a very energy intensive process requiring considerable amounts of steam and electricity. Sugar mills, therefore, self generate the steam and electricity needed for their industrial process. The fuel used is either fossil fuel (natural gas or fuel oil) or bagasse resulting from cane crushing.

During the sugar production process in the mill, a number of by-products and residues are generated. These are:

- Bagasse, which is the fibrous material remaining after chopping and milling from juice extraction.
- Filter mud/cake resulting from cane juice filtration.
- Furnace ash, in case the bagasse is burnt in the boiler for steam and electricity generation.

According to personal interviews conducted with the operation managers of a number of sugar mills in Egypt, the percentage of by-products and co-products generated during the sugar production process are as follows:

- 30% bagasse
- 3.5% Filter mud/cake
- 0.4% Furnace ash

Based on the above estimates and the amount of cane detailed in Table 2, the amounts of residues produced from the sugar cane factories of Upper Egypt are shown in Table 3.

Table 3. Amount of waste generated during sugarcane manufacturing process

Governorate	Factory	Processed Cane (tons)	Bagasse (tons)	Molasses (tons)	Filter mud/cake (tons)	Furnace Ash[3] (tons)
El Menia	Abou Korkas	408,085	126,506	16,731	14,283	1,632
Sohag	Gerga	531,633	164,806	21,797	18,607	2,127
Qena	Nagaa Hamadi	1,435,137	444,892	58,841	50,230	5,741
	Deshna	811,497	251,564	33,271	28,402	3,246
	Kous	1,496,836	464,019	61,370	52,389	5,987
Luxor	Armant	1,320,602	409,387	54,145	46,221	5,282
Aswan	Edfu	1,199,351	371,799	49,173	41,977	4,797
	Komombo	1,821,253	564,588	74,671	63,744	7,285
Total		9,024,394	2,797,562	370,000	315,854	36,098

[3] In case the bagasse used as fuel in the sugar mill for generation of steam and electricity

PROBLEM DEFINITION

The sugarcane industry generates considerable amount of residues during harvesting. Cane green tops are collected by the laborers responsible for harvesting to be used as animal fodder. However, it is not totally utilized as the animals consume only a portion of it. The remaining dry portion is mixed with animal manure and left to decompose. Decomposition of the dry cane tops with manure leads to emissions of greenhouse gases, such as methane, and loss of organic content of the cane tops that could have been utilized as fodder or fertilizer.

As for the dry leaves, they are left behind in the field and in cooler Governorates are used to protect the stubbles from winter frost during the months of December and January and early February. However, during March and April it is daily burnt as it is believed by the farmers that the practice of burning the green leaves in the field eliminates weed population and kills all the different life cycle stages of pest insect species [4]. Burning of the cane dry leaves in the fields during the five months of harvest, have the following detrimental environmental impacts:

- Degradation of the air quality in the field area and downwind the fields due to the emission of combustion products such as, carbon monoxide (CO) and volatile organic carbons (VOC), which contribute to photochemical ozone creation potential (POCP), as well as acidification and eutrophication effects [2].
- Negative health impacts on the neighboring communities as a result of air pollution.
- Loss of the organic content of the leaves and nutrients that are burnt.
- Production of fly ash, which damages the soil microbial diversity [5].

During the sugar production process in the mill, three million tons of bagasse are generated annually, 316 thousand tons of filter mud and 36 thousand tons of furnace ash.

The filter cake/mud, which is a dark spongy solid, is continuously collected and sold to contractors to be used as soil amendment or fertilizer, due to its richness in nutrients. Filter mud has been applied on soil to decrease soil degradation from erosion and compaction, as it prevents crusting and cracking, adjusts the pH, improves drainage and encourages growth of bacteria and microorganisms [6]. However, due to the high moisture content of the filter cake, which is about 70%, and its composition makes it hard to handle and transport, it may result in the following environmental impacts [6]:

- The cake is smelly and attractive to insects and pests and easily ignitable when exposed to sunlight.
- It has a high BOD5 (55 kg/m3) which is a potential of water pollution in case it reaches a water body through direct contact or leaching. In addition, the high phosphorous and nitrogen content of the cake can cause water eutrophication.
- Direct application of the filter cake on land may contribute to greenhouse gas emissions when carbon is converted to carbon dioxide and methane.

Bagasse, on the other hand, is used for different purposes in different sugar mills. It is used for steam and power generation in Nagaa Hamadi Sugar Mill, in the manufacture of fiberboard in Deshna Sugar Mill and in pulp and paper manufacture in Kous Sugar Mill as it is composed of about 50% cellulose. Each of these uses has its environmental advantages as well as its drawbacks.

Bagasse has a gross calorific value of 19,250 kJ/kg at zero moisture and 9,950 kJ/kg at 48% moisture [7]. The bagasse burnt in the boiler provides the steam needed for electricity generation of the mill and for heating the sugar production processes. Usually, bagasse as fuel is complemented with other fossil fuels, such as heavy fuel or natural gas, to fulfill the power requirements in case of low bagasse intake. Bagasse is considered a renewable reliable and cheap source of energy and its combustion is CO_2 neutral as it is of biogenic origin. It also results in lower combustion emissions as compared to fossil fuels. However, direct burning as a fuel to generate steam and electricity has the following major negative impacts [8]:

- Contamination of the ambient air quality of the surrounding environment by the fly ash generated from burning bagasse in its loose bulky form. Sugar mills require expensive scrubbers and filters to collect these emissions. The installed pollution control devices are not always working effectively.

- Loss of resources as the ash generated in burning is lost to the atmosphere and cannot be obtained due to the bulkiness of bagasse and the lack of control over the burning process. The fly ash is rich in nutrients, which can be processed and used efficiently as a fertilizer.
- Energy inefficiency due to the bulkiness of bagasse causes it to have a low energy content per unit volume and leads to a low burning efficiency of 60%. In addition, due to the uncontrolled burning, approximately 30% of the bagasse by weight, does not burn in sugar mills. This bulk is disposed in dumpsites instead of being utilized.
- Bagasse is usually supplemented by another fuel such as fuel oil to enhance the burning efficiency, which aggravates the air polluting emissions due to high sulfur content of the fuel oil.

As for utilizing bagasse in fiberboard manufacturing, it avoids impacts associated with growing and harvesting wood trees to manufacture wooden board, i.e. avoids use of virgin wood and decreases energy use since there is less processing and drying required when bagasse is used. However, the following environmental impacts are generally associated with fiberboard manufacturing:

- Dryers release wood dust, carbon monoxide, carbon dioxide, nitrogen oxides, fly ash, volatile organic carbons (resins and fatty acids) and formaldehyde compounds (due to the use of urea formaldehyde).
- It is an energy demanding industry for generation of electricity and steam.
- The pith produced from the depithing process that is burnt in the sugar mill boilers contributes to fine particles emitted from stack boilers and leads to loss of nutrients that could be used as animal fodder.
- Fermentation of bagasse stored in wet form may cause emissions of foul smells to the neighboring environment.

Moreover, manufacture of pulp and paper from non virgin material such as bagasse consumes less water, energy, chlorine and raw material, and generates less greenhouse gases and methane emissions than virgin material or wood [9]. The environmental impact due to bagasse pulp production is more controlled compared to rice straw pulping, due to the different chemical properties of the effluents [10]. Although rice straw is available at a minimal cost, the economic effectiveness is relatively low due to unavailability of proven technology for chemical recovery of silica content from the resulting black liquor [10]. Furthermore, a typical mill for soda or kraft pulp using bagasse in Egypt generates energy in the form of steam and electricity from recovery boilers [10].

Nevertheless, a number of significant environmental impacts are associated with pulp and paper manufacture from bagasse due to air emissions from the recovery boiler, the lime kiln and any auxiliary boiler consisting of particulates, sulfur compounds derived from fuels, process chemicals in sulfate pulping and nitrogen oxides from combustion processes. Moreover, foul smelling emissions (reduced sulfur compounds originating from the spent cooking liquor) arise from the fiber line washers and liquor tanks in a sulfate pulping line [10]. Wastewater is also generated in large quantities and if not efficiently treated could cause considerable pollution.

OBJECTIVES

Agricultural and agro-industrial residues are rich sources of organic nutrients required to enhance the fertility of the soil and nutritional content of the animal fodder. Lack of natural fodder and fertilizer is one of the pressing issues in Egypt and reuse of residues in their production is considered one of the most sustainable reuse options. However, its implementation requires that the following factors must be taken into consideration:

- Seasonal availability of the waste
- Inconsistency in the composition of waste
- Need for initial investment
- Operation and maintenance cost of equipment
- Transportation and storage costs, in case reuse is not carried out on site.

Usually, low-cost simple options that are relying on natural biodegradation of organic material offer the most sustainable options. This research will propose options for transforming the residues generated during sugar cane harvesting and milling into silage and compost.

The choice of treatment, reuse or recycling method for each by-product or waste depends not only on its economic viability but also on its environmental sustainability. The ideal situation is to transform the sugar cane industry into an environmentally balanced industry with the aim of achieving zero pollution or waste. The sugar industry in Egypt is already on the road of achieving environmental balance as it established major industries such as fiberboard and pulp and paper to utilize its residues. However, sustainable performance of the industry could be achieved by closing the cycle of the sugar cane production process and integrating the residues resulting from the harvesting and sugar production stages in the creation of more environmental products with minimal cost and technology.

The aim of this research is to develop an environmentally balanced industrial complex (EBIC) for sugar cane industry in Egypt to approach zero pollution through analyzing the current practices of reuse/recycling of by-products/waste generated from the sugarcane industry from its agricultural and industrial stages.

HISTORICAL EFFORTS IN GREENING THE SUGAR INDUSTRY

Green Industry and Industrial Ecology

According to the United Nations Industrial Development Organization (UNIDO), green industry can be defined as "industrial production and development that does not come at the expense of the health of natural systems or lead to adverse human health outcomes". Green industry aims is reduce the significant impacts imposed on the human beings' health and conserve the environment's natural resources through the efficient use of resources, and efficient methods of production and manufacturing. The UNIDO recommends that are two main methods to achieve green industry: either by greening the existing industries or by creating green industries.

Greening of existing industries means more efficient use of resources, expanding use of renewable energy sources, phasing out toxic substances and improving occupational health and safety at the industrial level. As for the creation of green industries, it involves planning for the use of renewable and efficient energy, minimizing use of material through is recovery, recycling and reuse and finally control of pollution through environmental-friendly waste management plans.

The concept of "industrial ecology", which started in the 1990s, encouraged "waste utilization" rather than "waste treatment" [11]. Industrial ecology borrows from nature the notion of cycling. It promotes the idea that the industrial system should imitate the natural one by conserving and reusing resources entirely in production and consumption.

The objective of industrial ecology is to avoid environmental damage from the beginning through systems analysis, product, process, and facility design, and through technological innovation. It increases eco-efficiency and preserves the environment by minimizing the environmental impacts to regulatory limits [12].

The perception of industrial symbiosis (IS) is based on the scheme of exchange of a facility's waste in terms of energy, water or material with another facility and becoming its feedstock and Extended Producer Responsibility (EPR) means that the producers assume responsibility of their products even after use. The main focus of industrial ecology is waste minimization and the conversion of by-products into reusable products or resources [13]. Industrial ecology is most effective when there is a cluster of industries that can exchange their waste and by-products. Proximity allows for savings and economies of scale and reduces operational costs due to sharing of common services or suppliers [13]. Agglomeration of industries with similar waste and by–product allows for concentrating and minimizing waste collection costs and encourages other industries to reprocess the waste and sell it to neighboring manufacturers to use it as raw material.

According to Roberts [13], the principles of industrial ecology are:

- Establishing partnerships with communities and government in promoting the idea of sustainable industries

- Planning for industrial clusters to benefit from the concentration of by-products, waste material flows and energy surplus
- Co-location of industries involved in the trade or exchange of waste and by-products
- Valorization of waste and energy through recovery practices
- Innovation in the fields of cleaner production, waste management and sustainable industry development
- Provision of ‘smart infrastructure’ to sustain the growth of eco-industries
- Encourage innovation and marketing of new products developments through policies and incentives

Eco-Industrial Parks

Eco- industrial parks (EIPs) are based upon industrial ecology principles promoting the clustering of industrial facilities with the aim of minimizing energy, water and material wastes through their exchange among the industries [12]. EIPs close the material and energy flows within an industrial economy. EIPs are considered to be on the path of sustainable industrial development [13].

EIP aims at achieving economic, environmental, social and government benefits. Economic benefits are achieved through the reduction of costs of raw material, energy, waste management and treatment, where environmental gain is attained through reduction in use of natural resources as well as emissions and waste that cause environmental degradation [12]. Social benefits, on the other hand, ~~is~~ are recognized through the provision of new job opportunities and governmental profit is due to the reduction in cost of environmental degradation, demand on natural resources and infrastructure [12].

Eco-industrial parks related to the sugar industry exist in China as one of the strategies for implementing sustainable development. In China, the Guitang Group Sugar Complex has implemented an approach of integrated life cycle management that link material life cycles into increasingly complex webs with the aim of developing an eco-industrial park. Guitang group categorized the output material to any process as:

- Products which are the desired products of the process and represent the greater part of the value added.
- Co-products representing significant value, although not produced intentionally.
- By-products which are not intentionally produced, but they represent a modest positive value less than that of the original raw material.
- Residual products which are the process wastes including emissions to the atmosphere, soil and water. They represent a negative value as one has to pay for their disposal, treatment or processing.

The eco-park is composed of two chains: the alcohol chain and the paper chain. The alcohol chain consists of the sugarcane farm, sugar refinery, an alcohol plant and a fertilizer. The down-stream plant utilizes the waste resulting from the up-stream plant as its raw material [14]. Molasses, a co-product of the sugar plant, is used by the alcohol plant, the residue of which is used in the production of fertilizer. The second chain adopts the same concept as the pulp plant uses the bagasse generated from the sugar refinery and sends its wastes of white sludge to cement factories.

The Guitang Group reduces the wastes generation, improves their financial performance, treats the residual products, and even partly achieves waste recovery. Examples of those measures are:

- The waste liquid from alcohol production is re-used after treatment to be used to produce fertilizer that is sold to the raw material producer, the sugarcane farmers.
- Wastewater produced during paper making is difficult to dispose and so it is reduced between 30% and 40% through improved water efficiency. The resulting wastewater is filtered in the boiler house using the boiler slag and further treated to meet national standards and is then discharged into rivers.
- The filter mud produced during sugar refinery is dried and is used as raw material for cement production.

Environmentally Balanced Industrial Complex

Another concept related to sustainable industries and the concept of zero pollution is that of environmentally balanced industrial complex (EBIC), as introduced by Nemerow and Dasgupta [15]. EBIC is a "selective collection of compatible industrial plants located together in a complex to minimize environmental impact and industrial production costs" (Nemerow, 1995). The waste of some industries is used as raw material of other industries, thus minimizing transportation, storage, disposal costs of waste and cost on virgin raw material.

Nemerow [7] suggested that EBICs are best suited for large waste consuming and waste producing industries such as fertilizer plants, cement plants or sugar plants. The waste of the large industry may be suitable to be reused by other small scale industries that could prepare this waste to be used as raw material by other ones in the complex. Solid waste is only "misplaced raw material" as it can be used to replace the raw material of some industry and make a valuable product [7].

But before matching industries, the following issues need to be addressed:

- The physical distance between the waste producer and consumer
- The economics of joining the two industries
- The degree of compatibility of the waste material to be used as raw material of the other.

Nemerow and Dasgupta [15] proposed a number of environmentally balanced sugar cane complex or a "closed loop" complex that would result in zero waste. One of the EBICs that he proposed was the "sugarcane-power-alcohol complex" that includes: (1) a sugarcane refinery; (2) a power plant producing both steam and electricity; (3) agricultural land for growing sugarcane and (4) an optional alcohol production plant. The core of this complex is an anaerobic digester, which treats the main residues; bagasse and filter cake. The four major products of the complex are: refined sugar, electrical energy, molasses and alcohol (optional), in addition to fermentation mash, digested and filtered sludge, digester gas, and steam [11]. Another optional unit was an Algae Growth Basin utilizing the runoff of fertilizer and pesticide residues mixed and reused with excess water from the growth basin of sugarcane growing area.

The other complex that was proposed involved the compressing of bagasse and filter cake at high temperature into density packed briquettes. The cake acts as a binding agent due to its fat and wax content. The resulting briquettes acted as fuel for boilers as they have a calorific value of 15000 [kJ/kg] [12]. The precipitating ash in the boiler can be used as fertilizer.

PROPOSED ENVIRONMENTALLY SUGARCANE BALANCED COMPLEX IN EGYPT

The sugarcane industry in Egypt can be currently defined as an open industrial system that consumes material and energy and creates products and wastes [12]. For the sugarcane industry to become a sustainable industry or a green industry, its production process has to be closed over its lifecycle. Its wastes, residues and by-products should not be burned or disposed but should be rather treated as raw material for other industries. The sugarcane industry in Egypt needs to introduce the concept of green industries and industrial ecology.

The first open system is the one of sugar harvest as the residues are either burnt like the dry leaves or partially consumed as animal feed as is the case of the green tops. The authors proposed to produce silage from the green tops to provide the farmer with a secure supply of natural fodder that is of acceptable quality. The Egyptian farmers are already producing silage from corn and they can produce use the same ensilaging technique to produce silage from green tops. The authors have produced silage of acceptable quality from the green tops on a pilot scale. As for the dry leaves, the authors experimented with producing compost out of it through shredding it and mixing to with animal dung or filter cake/mud produced from the sugar mills to adjust the C/N ratio. Producing compost or organic fertilizer out of the green leaves will have a number of positive environmental impacts resulting from avoiding air pollution resulting from the leaves' open burning and replacing some of the chemical fertilizers that were used by the farmers in their fields.

As for the milling stage and in case the bagasse is not utilized as fuel or fiber, it is proposed and tested by the authors to produce compost or organic fertilizer out of the bagasse in combination with the filter cake/mud. The produced organic fertilizer was also found to be good quality and its NPK content able to replace a good portion of those of the chemical fertilizers. The authors are also experimenting with producing silage out of the bagasse. The filter cake/mud and furnace ash are a treasure of nutrients but applying them directly on reclaimed lands may cause undesirable outcomes as "phytotoxicity and soil nitrogen immobilization" [16]. Composting the filter cake alone or with furnace ash in a ration similar to that produced from the mill will result is high value organic fertilizer that is safe and is of high quality. Moreover, the effluent and sludge generated from the sugar mill's industrial wastewater treatment plant can also be added to the composting mixtures.

It is therefore recommended to make a number of small scale silage and compost facilities within the agricultural fields to produce silage from the green tops and compost from the dry leaves. A bigger central composting plant is to be established within the sugarcane mills to produce compost and organic fertilizer from filter mud, furnace ash and excess bagasse.

To assess accurately the environmental impacts associated with each scenarios of waste/residue management in the field and the mill and to quantify environmental improvement resulting from the authors' proposal as compared to current practices, life cycle assessment will be conducted from each management option. Figure 1 shows the current waste/residue management options in pink boxes and the proposed reuse options that would close the natural cycle in green boxes.

Figure 1: Closing the Material Cycle of the Sugarcane Industry in Egypt

CONCLUSION

The sugarcane industry in Egypt needs to work on the closing of its material cycle to reach sustainability. The wastes and residues generated from the harvesting process are not efficiently used but rather burnt or disposed. Re-using the agricultural residues to produce useful products that can be returned to the field will achieve sustainability in the first phase of sugarcane production, which is cultivation and harvesting. It is recommended to reuse the cane tops and dry leaves to produce animal feed and organic fertilizer to be returned to the cane cultivation phase. The reuse methods proposed are simple, low cost and could be applied by the farmer on a small scale.

As for the sugarcane milling stage, the material cycle can also be closed by reusing in a sustainable manner the industry's main by-products which are bagasse, filter cake and furnace ash. Bagasse reuse in power generation and production of paper and fiberboard are already utilized. More simple low cost option for reuse of bagasse is the production of compost or organic fertilizer in combination with the filter cake and ash and the production of animal fodder. The output from the fertilizer or fodder option will also close the natural cycle as it will be returned to the farmers and cane fields.

Closing the natural and material cycle throughout the life cycle of the sugarcane industry will transform it from a non sustainable industry to an environmentally balanced industry.

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BIOGRAPHY

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